**Challenge Set 1.**

These problems involve a mixture of the probability distributions.

Some may involve more than one. Always name the distribution that you are using and state its parameters.

All of these problems are set at Merit, Excellence or Scholarship level.

**Problem 1 (Merit)**

On a particular stretch of road, accidents occur at an average rate of one per 4 working days.

1. What assumptions must you make in order to use the Poisson Distribution to model the number of accidents that occur in a given day in this stretch of road. Are you confident that these assumptions are all satisfied?
2. Suppose the conditions required for the Poisson Distribution *are* satisfied, calculate the probability that in a given working week (5 days):
   1. There are no accidents on Monday and Tuesday, but each of Wednesday, Thursday and Friday has at least one accident.
   2. At least 3 days are accident-free. *(Hint: requires a different probability distribution)*

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**Problem 2 (Merit and Excellence)**

A large airline suffers from randomly-occurring equipment faults requiring replacement aircraft on 90% of all days.

Flights need to be cancelled if there are three or more cases of faulty aircraft per day, because there are only two replacement aircraft.

1. Calculate the mean number of equipment faults per day.
2. Given that at least one replacement aircraft had to be used, calculate the *conditional* probability that only two flights had to be cancelled.
3. Calculate the mean number of **replacement aircraft** used per day.

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**Problem 3 (Merit and Excellence)**

Faults occur randomly on a printing machine, which produces wallpaper which is later wound up into rolls. Any roll with a defect is rejected; this happens to 16% of the rolls.

1. Calculate the mean number of faults per roll.
2. What is the probability that a rejected roll has at least two faults.
3. To cut down the number of rejected rolls, the manufacturer decides to halve the amount of wallpaper on a roll. Find the percentage of rolls which are now rejected.

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**Most of the remaining problems have been asked before in either a Scholarship exam or in NCEA at Excellence level**

**Problem 4 (2010 NCEA Merit & Excellence)**

1. A farmer grows onions and plants them in rows which are 50 metres long.

The farmer needs to know the number of onions that will be diseased.

To investigate this, he divides one row of onions in a paddock into 5 sections, each 10 metres long, and counts the number of diseased onions in each section.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | **1st section** | **2nd section** | **3rd section** | **4th section** | **5th section** |
| Number of diseased onions | 13 | 17 | 9 | 9 | 12 |

Use the information in the table above to find the probability that, in a **5 metre section**, more than 4 onions will be diseased.

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1. The farmer estimates that, for each day of onion harvesting, the probability of two or more workers calling in sick is 0.2 and that the probability of one worker calling in sick is 0.35.

Find the expected number of workers calling in sick each day of onion harvesting.

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**Problem 5**

The final series of the America’s Cup between two yachts is organised so that the winning yacht is the first one to win five races out of a possible total of nine races.

Calculate the probability that **not all nine races** are needed to find the winner. Assume that each yacht is equally likely to win each race, and that the results of the races are independent.

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**Problem 6**

Andy and Bernie are shooting arrows at a target. At each turn, the player with an arrow closest to the centre scores a point. Each player is equally likely to be closest.

They take 25 turns, and the player with the highest score wins.

After 10 turns Andy has a score of 7.

What is the probability that **Bernie** wins the game?

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**Problem 7**

The emergency locator beacon on a ship uses batteries which are installed when needed from a packet of 11.

The packet is labelled ‘*average life = 12 hours*’.

The life of these batteries is normally distributed with standard deviation 0.7 hours.

1. Calculate the minimum length of time you would expect 95% of these batteries to last for.
2. An emergency arises, and all 11 of the batteries are used, one after the other. Calculate the probability that the *total* length of time that the 11 batteries last exceeds 135 hours.
3. Calculate the probability that exactly 4 of the batteries from the packet each lasts more than 13 hours.

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**Problem 8 - The Geometric & Negative Binomial Distributions** *(Sometimes in Scholarship)*

You throw a fair six-faced die, observe which number is facing upward, and then throw it again, repeating this until you roll a 6 for the first time:

1. Calculate the probability that it takes:

**i.** exactly 2 throws to get your first 6: \_\_\_\_\_\_\_ **ii.** exactly 3: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

1. Write down a **calculation** for the following probabilities but **do not evaluate them**:
   * 1. The probability that it takes exactly **5** throws to get your first six.

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* + 1. The probability that it takes exactly **10** throws to get your first six.

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1. Write down an expression for the probability that it takes exactly ***m*** throws to get your first six. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
2. The **Geometric Distribution** is another probability distribution that is related to the Binomial Distribution.

If independent trials are carried out, each of which has two possible outcomes defined as ‘success’ and ‘failure’ with constant probability ****** of success, we use the Geometric Distribution to model the number of trials ***m*** up to and including the first success.

Based on your answer to (c), write down an expression for **P(*M=m*)**, the probability that the ***mth*** trial results in the **first** **success**.

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1. Returning to the dice experiment, what is the probability that:
   1. The third roll of the die results in the **third six** (i.e. all 3 are sixes)? \_\_\_\_\_\_\_\_\_\_\_\_\_
   2. The **fourth** roll of the die results in the **third six?**

Hint: This is equal to = P(Binomial: 2 successes in 3 trials) × P(success on 4th trial)

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* 1. The **seventh** roll of the die results in the **third six? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**
  2. The ***m***th roll of the die results in the **third six? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**
  3. The ***m***th roll of the die results in the ***k***th **six**? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

1. Write down a simplified expression for the probability that, in a sequence of independent trials with probability of success ****** in each, the ***m*th** trial results in the ***k*th** success (this is known as the ‘*Negative Binomial Distribution’*).

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**Problem 9 (2004 NCEA Merit & Excellence)**





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**Problem 10 *(A classic Scholarship problem)***

On average, 30% of smokers can give up successfully on the first attempt.

In a random sample of ***n*** smokers who intend to make their first attempt at giving up smoking, find ***n*** so that there is 0.9 probability that at least 30 of them give up successfully.

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**Problem 11 (*Scholarship Statistics and Modelling 2010)***

On average, 3% of new Statsmobile cars have minor defects that occur randomly.

In a random sample of ***n*** new Statsmobiles, find ***n*** so that there is a 0.2 chance of no more than one Statsmobile having a minor defect.

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**HINTS**

**Problem 1:**

**(b) NOTE: We’re told to assume that the conditions required for using the Poisson Distribution to model the frequency of accidents are met. Therefore we may assume that accidents occur independently on each day.**

**(i)** Hence, P(no accident on Monday and Tuesday) = P(no accident on a given day)2

P(at least one accident on a given day) = 1 – P(no accident on a given day)

P(at least one accident on each of Wed, Thurs, and Fri) = P(at least one accident on a day)3

**(ii)** This is **Binomial** since there is a **fixed number of independent trials**: 5 days, and **each day has 2 possible outcomes**: accident free or not.

**Parameters:** ***n*** = 5 days. ****** = P(no accident on a given day).

Let *X*= number of days that are accident free.

**Problem 2:**

1. **Poisson** – **discrete** events occurring at random within a **continuous interval**.

Asked the value of ****, the mean number of faults per day. So an inverse problem.

**Let *X*: Number of faults in a given day.** P(*X* > 1) = 0.9 (from info in question)

**(b)** *2 replacement aircraft, so 1 flight cancelled if there are 3 faults (both spares used). So 2 flights would be cancelled if there were 4 faults in a day.*

P(2 flights cancelled │at least one replacement aircraft needed)

= P(*X* = 4 │ *X* > 1)

= 

= 

**(c)** Let ***Y*** : Number of **replacement aircraft needed** in a given day. Then the probability distribution of *Y*  is given by:

|  |  |  |  |
| --- | --- | --- | --- |
| ***y*** | 0 | 1 | 2 *(Note: this is occurs if there are 2 or more faults)* |
| **P(*Y*=*y*)** | 0.1 | ? | ? |

**Problem 3:**

1. **Poisson** – **discrete** events occurring at random within a **continuous interval**.

Asked the value of ****, the mean number of faults per roll of wallpaper. So an inverse problem.

**Let *X*: Number of faults on a given roll of wallpaper.**

**(b)** *Rejected if it has 1 or more faults.* P(At least 2 faults │Rejected) = P(*X* > 2 │ *X* > 1)

**(c)**As a Poisson variable, the frequency of a fault is proportional to the size of the interval in which it occurs. So halving the amount of paper in the roll will halve the mean rate of faults.

**Problem 4:**

1. **Mean** number of diseased onions **per 10 metre section** = = 12

**** Assuming that the diseased onions occur independently and at random and that their frequency is proportional to the length of row, we can model it using the **Poisson Distribution**.

Then the mean number of diseased onions in a **5 metre section** is **** = ?

**(b)**This is an inverse problem, need to find **** the expected number (i.e. mean) who call in sick per day.

Let *X*: Number of workers calling in sick in a given day.

From info in question: P(*X*=1) = 0.35; P(*X* > 2) = 0.2 **** P(*X*=0) = ?

**Problem 5:**

P(Not all 9 races needed) = 1 – P(9 races needed)

= 1 – P(score is “*4-all”* after 8 races)

**Problem 6: A** stands for Andy; **B** stands for Bernie. After 10 turns, score must be 7:3 to A.

Therefore B is down 4 points. So he must score at least 5 points more than A in the rest of the game.

**Problem 7:**

**(a)** Inverse Normal Distribution problem: With ****** = 12 hours, ****** = 0.7 hours.

Need to find *x* such that **P(*X* > x) = 0.95.**

1. Let ***T*** : Total length of time that all 11 batteries last for.

***T*** has mean ***E(T)* = 11(12)** and **standard deviation** 

**(c)** Let ***Y*** : Number of batteries from packet that last > 13 hours.

***Y*** is a **Binomial** random variable (11 independent trials, each of which has 2 poss. outcomes).

Parameters are ***n*** = 11 batteries in packet. ****** = P(an individual battery lasts > 13 hours)

**Problem 8:**

1. Calculate the probability that it takes:

**i.** P(exactly 2 throws to get your first 6) =  **ii.** P(exactly 3) = 

1. Returning to the dice experiment, what is the probability that:

ii. The **fourth** roll of the die results in the **third six?**

Hint: This is equal to P(Binomial: 2 successes in 3 trials) × P(success on 4th trial)

= 

iii. The **seventh** roll of the die results in the **third six?** 

**Problem 9:**

**Binomial Distribution. Need to approximate it with either Normal (with a continuity corr.) or Poisson.**

**Are both *n* and *n(1-)* > 5 ?**

**Problem 10:**

Binomial inverse problem:

Need to take the complement: i.e.

Cannot solve algebraically because we’re dealing with 31 discrete cases (0🡪30).

So need to approximate using the Normal Distribution, with

*Using a continuity correction.*

And since (from the info in the question), , then:

Need to find *n* such that  . i.e. from tables/GC, z= -1.2815

Therefore: . Remove the surd by squaring both sides. Then solve for *n*.

**Problem 11:**

Binomial distribution. Parameters are ***n*** : number of Statsmobiles in the sample (chosen randomly).

****** : probability that a randomly chosen Statsmobile has a defect.

where ********= 0.03**.

Let *X* : number of Statsmobiles in the sample that have defects.

We’re told that P(*X* < 1) = 0.2. Asked to find the required number of trials (Statsmobiles), ***n***.

2 alternative methods were accepted as correct (despite rendering *slightly* different answers):

METHOD A: Using Binomial Distribution directly, forming an equation and using technology to solve it.

or METHOD B: Use a *Poisson Approximation*.